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Under our conditions of observation, red-green-blind persons of the ordinary type (deuteranopes or 'green-blinds') find an equation  $60^\circ R + 60^\circ B = 60^\circ G$  fairly satisfactory in hue. A better testing equation, for hue and tint together, is  $60^\circ R + 58^\circ B = 45^\circ G$ .

Red-green-blind persons of the less common type (protanopes or 'red-blinds') may be tested by the equation  $60^\circ R + 43^\circ B = 34^\circ G$ .

These figures are given with the reserve made necessary by the fewness of our observers. Color-blind subjects must be waited for, and their time is not always at the psychologist's disposal. We hope to repeat the observations in further instances.

#### XLVI. ADAPTATION OF SUPERFICIAL PAIN

By H. H. STRAUS and R. F. UHLMANN

As a rule, the authors who discuss pain say nothing about adaptation. Their silence probably means that, under ordinary circumstances of stimulation, adaptation is not observed: perhaps because the phenomenon is not insistent enough to force itself generally upon attention, perhaps because the facts themselves point to continuity of pain with continued stimulation. Continuity is, indeed, suggested by the result of continuous intensive stimulation and by instances of pathological pain, as of course also by the effect of intermittent stimulation even if weak; but adaptation may very well occur with weak continuous stimulation. Cases of the disappearance of pain so aroused have, in fact, been reported. Murray "makes the accidental discovery that superficial pain adapts out almost as readily as superficial contact." She remarks further that "mapping of the same area for pain [as had previously been mapped by a needle-stimulus] with an overheated brass rod, lightly applied, gave practically identical results as regards the position of the points and the occurrence of fatigue."<sup>1</sup> There are also passages in von Frey's writings which indicate a like observation. "Der Cornea (und Conjunctiva) eigenthümlich ist ferner die Erscheinung, dass ein nicht weit über der Schwelle liegender Reiz (1—5 gr/mm<sup>2</sup> für die Cornea) an vielen Punkten im ersten Moment der Berührung nicht gefühlt wird, dass aber bei andauernder Berührung Schmerzempfindung auftritt, die entweder nach einigen Sekunden wieder verschwindet, oder was häufiger der Fall, soweit anschwillt, dass die Reizung unterbrochen werden muss."<sup>2</sup> Again, in speaking of the conditions of pain in general, von Frey remarks: "Bei andauernder Deformation ist die Schmerzempfindung, schwächste Reize ausgenommen, andauernd."<sup>3</sup> It seems, therefore, that under

<sup>1</sup> E. Murray, A Qualitative Analysis of Tickling, *Amer. Jour. Psychol.*, 1908, xix, 304; 305.

<sup>2</sup> M. v. Frey, Beiträge z. Physiol. des Schmerzsinnns, *Ber. ü. d. Verhandl. d. Königl. Sächs. Ges. d. Wiss. z. Leipzig*, 1894, xlv, 1, 193 (italics ours).

<sup>3</sup> *Untersuch. ü. d. Sinnesfunctionen der menschlichen Haut*, 1896, 261 (italics ours).

experimental conditions the pain set up by continuous weak stimulation may disappear. But the observations thus far reported are casual, and no attempt has apparently been made to study the phenomenon of pain-adaptation systematically.

In this paper we report experiments which should be regarded only as preliminary to such a study. We were interested, first, to make out the exact conditions under which adaptation of pain may be experienced, and secondly to determine the times of adaptation with various intensities of stimuli.

*Procedure.* As the cutaneous area to be worked upon we chose the volar side of the fore-arm, about half-way between wrist and elbow. We attempted experiments upon the cornea, but without success; the stimulus started a flow of tears, and observation was impossible. At the beginning of work on the arm we shaved the area, and before every experiment softened the skin with soap and water. We found it advisable also, at the beginning of every period of observation, to localise anew three or four pain spots. These, we made sure, were not too near to pressure spots, and gave pure pain without pressure. Our first stimuli were human hairs, horsehairs and hog-bristles; but although we were able, after long periods, to secure pain-adaptation, we eventually, for reasons given later, abandoned these forms of stimulus. Thereafter we used a needle fastened to the shaft of a Head algometer;<sup>4</sup> the needle and shaft together were brought down upon the skin by means of the mechanical appliance described by Dimmick.<sup>5</sup> The arm rested in a plaster cast. We employed three intensities of stimulation; these, as measured on a pressure-balance, and including the friction of the instrument, were 3, 5.5, and 8 gr. respectively. The rate of application was constant; it was also gradual, as we wished to avoid piercing the skin by the needle.

The writers, S and U, served alternately as *E* and *O*, changing places after every few observations. Both had completed a qualitative laboratory-course, in which they had become especially interested in cutaneous qualities. At the beginning of these experiments they spent some time on practice-work, so that they were able to distinguish readily the qualities of contact (weak pressure) and weak pain.

*Results.* With the stimuli above described we have succeeded in obtaining adaptation of pain with a high degree of regularity. It is essential to success that there be no movement either of the stimulus-point or of the skin beneath the stimulus, and also that the intensity of the stimulus remain constant during the period of stimulation. It was mainly for these reasons that we discarded the hairs and bristles for the needle, and a manual for a mechanically controlled means of application. We often, it is true, obtained the phenomenon with hairs and bristles, but we failed no less frequently; and we found further that, after adaptation, it was almost impossible to remove the stimulus by hand without rearousing pain. We failed also when the stimulus was set down over or to the side of a vein, so that we were careful later to avoid veins when localizing pain spots. Finally, we failed whenever there was the slightest movement of the arm, so that the plaster cast became necessary.

In the quantitative experiments, in which we measured the length of the course of adaptation, we found it necessary to inhibit also

<sup>4</sup> H. Head, *Brain*, xxxiv, 1911, 197 (fig. 6.).

<sup>5</sup> F. L. Dimmick, *Amer. Jour. Psychol.* xxvii, 1916, 566.

bodily movement of any sort between stimulations. The reason was purely technical; the least displacement of the pain-spot required a realignment of the mechanical stimulator. To relieve the observer of discomfort we therefore reduced the interval between successive stimulations to 30 sec. The serial nature of our results (there is no decrease in the magnitude of the adaptation-times in successive trials) shows that in this period the pain-spot had sufficiently recovered.

The following table gives the adaptation-times in seconds for each observer and for all three of the intensities of stimulus.

Intensity of Stimulus	Obs.	No. Cases	Av. Adaptation Time in Sec.	Range of Adapt. Times
3.0 gr.	U	10	$5.0 \pm 0.6$	4—7
	S	10	$11.9 \pm 5.43$	7—26
5.5 gr.	<b>U</b>	20	$14.0 \pm 3.5$	8—31
	<b>S</b>	10	$26.3 \pm 7.5$	15—38
8.0 gr.	U	20	$19.0 \pm 5.85$	13—24
	S	10	$44.1 \pm 6.96$	27—72

The table shows a large individual difference, but the times for both observers increase progressively with increase in intensity of stimulation. The *m. v.*, particularly of S, are irregular; and the ranges indicate that the temporal course of pain-adaptation is exceedingly variable. The extremely long times never occurred more than once; we are unable to offer any explanation for them, except that, for all our precaution, some slight movement of the observer's arm may have taken place.